UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY

ENVIRONMENTAL AND PHYSICAL PROPERTIES OF THERMOPLASTIC CASSAVA STARCH/BEESWAX REINFORCED WITH COGON GRASS FIBER

RAJA MOHAMAD FAREEQ BIN R MOHAMAD FAUDZI

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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DEDICATION

Specially dedicated to my beloved parents, my brother and sister and to all family members, lecturers and friends.

ABSTRACT

Nowadays, plastic-based materials are being widely used for commercial and household purposes but, it has become a threat to the environment around the world. However, the development of biodegradable polymer from renewable resources has been promoted by increasing environmental awareness to replace conventional non-biodegradable polymer in various applications. Biodegradable polymer has attracted a lot of attention because of their environmentally friendly and sustainable to nature. Starch is an example of biodegradable polymer because of their advantage such as low cost, non-toxicity, biodegradability and availability to replace synthetic polymer in plastics industries. Unfortunately, starch has limitations to commercial because of highly moisture sensitivity and limited mechanical properties. Wax is a hydrophobic organic material with medium chain length and has potential to be used to improve to the properties of starch. Cogon grass (Imperata Cylindrica) is the most abundant green short plant which grows wildly in the rain forests of tropical countries and have no economic rate for agriculture. This waste has potential application to be used as reinforcement material for producing biodegradable polymer composite. In this study, blending thermoplastic cassava starch (TPCS) with beeswax as a matrix and using cogon grass fiber with different amount (10,20,30 and 40 wt.%) as reinforcement to enhance the properties of TPCS/Beeswax. Consequently, TPCS/Beeswax reinforced with cogon grass fibre composites were developed by using dry mixing and hot press method at 145°C for 1 hour. Hence, the objective of this research is to study the environmental and physical properties of the substance when mixed as composites. The physical properties of TPCS/Beeswax reinforced with cogon grass fiber were evaluated. The result show that the moisture and water uptake of the sample decrease when the cogon grass fiber loading increase. Besides, the thickness swelling result was affected during the testing because of the delamination and disintegration of the specimen and caused irregular results. The soil burial test has been done to observe the biodegradation of the TPCS/Beeswax cogon grass fiber composite on the environmental properties. The weight of the sample decrease for 2 and 4 weeks of burial. It shows that the higher the fiber load, the longer time taken for sample to degrade. Overall, the finding from the current study demonstrated that TPCS/Beeswax reinforced with cogon grass fiber has shown improvement in characteristic compared to original material. In conclusion, TPCS/Beeswax reinforced with cogon grass fiber composite are potential alternative material for biodegradable product i.e. disposable biodegradable tray packaging application.

ABSTRAK

Pada masa kini, bahan berasaskan plastik banyak digunakan dalam sektor komersial dan penggunaan isi rumah seharian tetapi penggunaannya kini telah menjadi ancaman persekitaran ke serata dunia. Walau bagaimanapun, kemajuan polimer biodegradasi berasaskan bahan yang boleh dipebaharui telah diperkenalkan dengan pencerahan kesedaran persekitaran bagi menggantikan penggunaan produk tidak mesra alam seperti produk yang berasaskan bahan tidak terbiodegradasi. Kemajuan polimer biodegradasi telah menjadi tarikan penggunaanya kini kerana ianya merupakan bahan yang mesra pengguna dan mesra alam. Sebagai contoh, kanji merupakan salah satu bahan polimer biodegradasi yang terbaik dengan kelebihannya yang murah, tidak bertoksik, mudah terlarut (degradasi), dan mampu untuk menggantikan sintetik polimer dalam industri plastik. Tetapi malangnya, kanji mempunyai kekurangan untuk dipasarkan kerana kanji adalah bahan yang mempunyai kepekaan kelembapan yang tinggi dan kekangan sifat mekanikalnya. Dalam masa yang sama, lilin pula merupakan bahan organik hidrofobik dengan rantaian sederhana dan mempunyai potensi untuk meningkatkan sifat kanji. Manakala lalang pula yang merupakan sejenis tumbuhan hijau yang tumbuh merata di segenap pelusuk hutan rimba yang tiada harga pasaran bagi sektor agrikultur dan ianya mempunyai potensi yang boleh digunakan sebagai bahan pengukuhan untuk menghasilkan bahan komposit polimer biodegradasi. Dalam kajian ini, campuran termoplastik kanji ubi kayu (TPCS), dengan lilin lebah sebagai matrik, dan penggunaan serat lalang yang berbeza kuantitinya (10,20,30 dan 40wt%) sebagai pengukuhan untuk meningkatkan sifat TPCS/Lilin lebah. Oleh itu, TPCS/Lilin lebah diperkukuhkan dengan serat lalang komposit telah dihasilkan dengan menggunakan pencampuran kering dan kaedah pengacuan mampatan pada suhu 145^{o}C selama satu jam. Dengan itu, objektif kajian ini adalah untuk mengkaji sifat persekitaran dan fizikal bahan tersebut apabila dicampurkan bersama komposit. dan sifat fizikal TPCS/Lilin lebah yang diperkukuhkan bersama lalang telah pun dinilai. Hasilnya menunjukkan kandungan kelembapan dan penyerapan air untuk setiap sampel berkurang apabila kandungan lalang serat ditingkatkan. Selain itu, perubahan ketebalan telah terjejas semasa kajian kerana penyinkirian dan perpecahan specimen dan menyebabkan keputusan tidak teratur. Kemudiannya, kajian penanaman tanah telah dilakukan untuk memerhatikan proses komposit biodegradasi TPCS/Lilin lebah serat lalang bagi mengkaji sifat persekitarannya. Seterusnya, berat sampel kajian menunjukkan pengurangan bagi minggu kedua dan keempat selepas penanaman. Hasilnya menunjukkan, lagi tinggi kandungan serat yang dimasukkan, lagi lama masa yang diperlukan untuk sampel dikompos. Secara keseluruhannya, hasil kajian ini TPCS/Lilin lebah yang diperkukuhkan lalang menunjukkan penambahbaikan sifat polimer biodegradasi berbanding bahan asal tersebut. Kesimpulanya, TPCS/Lilin lebah yang telah diperkukuhkan dengan komposit serat lalang merupakan salah satu potensi alternatif bagi bahan produk biodegradasi seperti applikasi pakai buang dulang pembungkusan biodegradasi.

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PE	-	Polyethene
PP	-	Polypropylene
TPS	-	Thermoplastic Starch
FT-IR	-	Fourier Transform Infrared Spectroscopy
SEM	-	Scanning Electron Microscope
TPCS	-	Thermoplastic Cassava Starch
EPS	-	Expanded Polystyrene
BDPSS	-	Biodegradable Plastic from Sago Starch
TGA	-	Thermal Gravimetric Analysis
DSC	-	Differential Scanning Calorimetry
$CaCO_3$	-	Calcium Carbonate
WVP	-	Water Vapour Permeability
RH	-	Relative Humidity
CS	-	Cassava Starch
LDPE	-	Low-Density Polyethylene
PVA	-	Polyvinyl Alcohol
PCL	-	Polycaprolactone
XRD	-	X-Ray Diffraction
MEKPO	-	Methyl Ethyl Ketone Peroxide
ASTM	-	American Society for Testing and Materials
MMC	-	Metal Matrix Composites
PMC	-	Polymer Matrix Composites
CMC	-	Ceramic Matrix Composites
MAPP	-	Maleic Anhydride Polypropylene

CHAPTER 1

INTRODUCTION

1.0 Background

Nowadays, plastic-based materials are being widely used for commercial and household purposes, such as polyethene (PE) and polypropylene (PP). However, increasing of non-biodegradable plastics are proving to be a threat to the environment around the world (Fakhrul & Islam, 2013). The development of biodegradable polymer from renewable resources has been promoted by increasing environmental awareness to replace conventional non-biodegradable polymer in various applications (Mendes et al., 2016).

Starch offers several advantages, including low cost, non-toxicity, biodegradability and availability for the replacement of synthetic polymers in plastics industries. Starch is not a thermoplastic, but in the presence of a plasticizer, it will act as a thermoplastic material under high-temperature conditions. Plasticizers are the most important agents to improve thermoplastic starch flexibility, processability and the properties of the starch will change depends on the quantity of plasticizer used (Sahari, Sapuan, Zainudin, & Maleque, 2013). Many variations of natural material have been used as reinforcement in polymer composites. The most common natural plant are hemp, jute, flax, kenaf, and sisal used as reinforcement in polymer composites (Akil et al., 2011).

The addition of natural material to polymer composites as reinforcement has created more eco-friendly composites and reduced dependency on conventional fiber such as fiber glass that poses manufacturing hazard. The best way for the industry to solve environmental issues for both the waste disposal problem and production of synthetic polymer is by developing environmentally friendly materials. This project is the continues project from the previous study. With using thermoplastic cassava starch and beeswax as a matrix because the previous study has shown that incorporation of beeswax improves the mechanical properties and reduce the moisture sensitivity and also use the cogon grass fiber as the reinforcement for the TPCS.

1.1 Problem statement

The petroleum-based polymer has created serious environmental issues, especially during the disposal stage because of the high use by the community around the world. All disposal waste was non-biodegradable plastic will affect the environment and cause a serious effect to nature and living thing (J Sahari & Sapuan, 2011). In addition, many countries have banned the usage of plastic bag to reduce environmental issues. Hence, to overcome the problem of the non-biodegradable polymer has to be replaced with renewable natural sources.

Cassava starch is one of the starches which was reported can be transformed into thermoplastic material by the presence of plasticizers with the application of thermo-mechanical energy in the heating process (Prachayawarakorn Jutarat & Pomdage Wanida, 2014). Unfortunately, TPS-based product has limitations to commercial because of highly moisture sensitive and limited mechanical properties. The proper changes should be made so that the properties of TPS material can be improved. Waxes are organic hydrophobic compounds, which are often used for waterproofing in wax paper or composites (Pervaiz,

Oakley, & Sain, 2014). Therefore, the potential modification used blending with beeswax and natural fiber as the reinforcement (Reis et al., 2018).

Lalang plant or cogon grass (Imperata cylindrica) is the most abundant short green plant that grows wildly in the rain forests of tropical countries including Malaysia. The plant was reported does not usually have any economic value and become one of the major problems to agriculture industries (Zamri, Rashid, Jamion, & Mohamed, 2012). This because planters need to spend a lot of money, energy, and time on their own populations to eliminate the competitiveness of agro-economic plants for nutrients, water and light. As a natural fiber, cogon grass is the main component that became one of the ingredients for the preparation of natural fiber polymer composites.

The project justification of this study is to develop thermoplastic cassava starch/beeswax reinforced with cogon grass fiber which comes from natural resources to solve the problem of an environmental issue and develop biodegradable polymer. Secondly, to characterize the physical and environmental properties whether the thermoplastic cassava starch, beeswax and cogon grass fiber is fully biodegradable material and can be safely disposed to the environment.

1.2 Objectives

1. To develop thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.
2. To study the physical properties of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.
3. To study the environmental properties of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.

1.3 Significance of study

The justification for this study are as follows:

i. The results of the current study can gain knowledge of biodegradable polymer developed from thermoplastic cassava starch and cogon grass fiber.

ii. The purpose of developing biodegradable polymer by increasing its properties in this study might overcome the environmental issues regarding the alternative of natural materials in replacing of the petroleum-based polymer.

iii. The environmental issue related to the petroleum-based polymer during processes, recycle and disposal can be eliminated by using fully bio-composite derived from cogon grass fiber.

1.4 Scope of study

In this study, cassava starch was used as the primary material. Thermoplastic cassava starch was developed by using glycerol as the plasticizer and modified with beeswax as the protective agent against moisture and water absorption. The physical properties were characterized by using Fourier transform infrared (FT-IR) spectroscopy, moisture content, scanning electron microscope (SEM), water absorption, moisture absorption, thickness swelling and environmental properties were carried out by water solubility and soil burial. Then, cogon grass fiber was added as reinforcement into thermoplastic cassava starch/beeswax to produced polymer composite. The modification of TPCS/Beeswax reinforcement with cogon grass fiber was performed by inserting different amount of cogon grass fiber (10,20,30,40 wt.%) into the polymer matrix to find the characteristic of their physical and environmental properties. Therefore, the application of the reinforcement of cogon grass fiber with TPCS/Beeswax as a biodegradable product.

1.5 Structure of thesis

The structure of this thesis is in accordance with the thesis format of Universiti Teknikal Malaysia, Melaka. This section represents a separate study that has the introduction, methodology, results and discussion, and conclusions. The details of the structure are as follows:

Chapter 1

This chapter clearly explained the problems related to this research and the objectives of this research. In the chapter also will be elaborated on the significance and scope of this study.

Chapter 2

This chapter provides a detailed literature review of the topic areas of this study. In addition, the research gaps obtained from the review were also clarified within the chapter.

Chapter 3

This chapter presents the methodology used in this study for the preparation of materials, testing procedure, and data collection.

Chapter 4

This chapter presents the result of Thermoplastic Cassava Starch/Beeswax and Thermoplastic Cassava Starch/Beeswax reinforced with cogon grass fiber. In this chapter, the result of physical and environmental testing for TPCS/Beeswax and TPCS/Beeswax reinforced with cogon grass fibre were analysed and discussed. The result also was elaborated within the chapter and relate with the objective of this study.